FINAL REPORT

PRELIMINARY PLANNING STUDY

WILLOW CREEK BASIN - INVENTORY OF STORAGE SITES

FOR

ALBERTA ENVIRONMENT

PLANNING DIVISION

JUNE 4, 1984

KLOHN LEONOFF
CONSULTING ENGINEERS

PA 1956.104

KLOHN LEONOFF
CONSULTING ENGINEERS

OUR FILE: PA 1956.104

June 4, 1984

Alberta Environment
Provincial Building
Planning Division
200 - 5th Avenue S.
Lethbridge, Alberta
T1J 4C7

Mr. L.K. Szojka, P.Eng.
Oldman River Basin Planner

Willow Creek Basin
Inventory of Storage Sites - Final Report

Dear Mr. Szojka:

We take pleasure in submitting the final report for the Willow Creek Basin Inventory of Storage Sites. As outlined in the report, two potential sites have been identified that have very similar benefits for water management in the Willow Creek watershed but are very different in concept. In one case, Site No. 2, a diversion of water from Willow Creek into Pine Coulee forms the basis of the concept; whereas, the other site, Site No. 3, which is further upstream, incorporates an onstream storage reservoir with the associated spillway and construction diversion works. Both of these potential storage sites have been equally ranked as it was not possible to differentiate between them based on the findings of this study.

We would like to extend our appreciation for the excellent co-operation afforded to us by yourself and Messrs S. Larson & R. Bennett. In addition we would also like to recognize the co-operation provided by the Calgary office of the P.F.R.A. with respect to Site No. 2 which had been studied by them in the 1950's.

If you have any questions or require any clarification of this report we would be pleased to meet with you at your convenience.

Yours very truly,

KLOHN LEONOFF LTD.

R.B. ELSON, P. Eng.
Manager, Water Resources Division

RBE/sh

Klohn Leonoff Ltd., #15, 6320 - 11th Street, S.E., Calgary, Alberta T2H 2L7 • Telephone: (403) 259-4114 • Telex: 03-824821

FINAL REPORT

PRELIMINARY PLANNING STUDY

WILLOW CREEK BASIN - INVENTORY OF STORAGE SITES

for

ALBERTA ENVIRONMENT

PLANNING DIVISION

June 4, 1984

PA 1956.104

KLOHN LEONOFF

TABLE OF CONTENTS

		Page
1.0	INTRODUCTION	1
2.0	METHODOLOGY	2
	2.1 Sources of Information	2
	2.2 Hydrology Studies	2
	2.3 Site Selection	3
	2.4 Conceptual Design Parameters	5
	2.4.1 Reservoir Capacity	5
	2.4.2 Dams	5
	2.4.3 Spillways	6
	2.4.4 Construction Diversions and Low Level Outlets	7
		7
	2.4.5 Water Supply	7
	2.5 Basis of Cost Estimates	7
	2.6 Environmental Aspects	9
3.0	POTENTIAL STORAGE SITES	9
	3.1 General	9
	3.2 Site 1 - Willow Creek Near Claresholm	10
	3.3 Site 2 - Pine Coulee	11
	3.4 Site 3 - Willow Creek Near Lane Creek	13
	3.5 Site 4 - Willow Creek Below Chain Lakes	14
	3.6 Site 5 - South Willow Creek	15
	3.7 Site 6 - Trout Creek	16
4.0	SUMMARY AND CONCLUSIONS	17
5.0	RECOMMENDATIONS	19

LIST OF TABLES

Table 1	Project Data
Table 2	Preliminary Comparison of Potential Reservoir Sites
Table 3	Resource and Environmental Land Classifications
Table 4	Capital Cost Summary
Table 5	Preliminary Ranking

LIST OF APPENDICES

APPENDIX I	Terms of Reference
APPENDIX II	List of References and Maps
APPENDIX III	Hydrology Studies
APPENDIX IV	Progress Report, March 19, 1984

LIST OF DRAWINGS

Figure 1 Willow Creek Basin - Locations of Potential Reservoirs
Figure 2 Site 1 - Reservoir Details
Figure 3 Site 1 - General Arrangement and Typical Sections
Figure 4 Site 2 - Reservoir Details
Figure 5 Site 2 - General Arrangement
Figure 6 Site 2 - Typical Sections
Figure 7 Site 3 - Reservoir Details
Figure 8 Site 3 - General Arrangement and Typical Sections
Figure 9 Site 4 - Reservoir Details
Figure 10 Site 4 - General Arrangement and Typical Sections
Figure 11 Site 5 - Reservoir Details
Figure 12 Site 5 - General Arrangement and Typical Sections
Figure 13 Site 6 - Reservoir Details
Figure 14 Site 6 - General Arrangement and Typical Sections
Figure 15 Cost Comparison

KLOHN LEONOFF

1.0 INTRODUCTION

The objective of this preliminary planning study was to identify potential on-stream and off-stream water storage sites in the Willow Creek drainage basin and to determine the order of magnitude costs to develop the sites. The study was, in essence, an office study based on available information including previous reports, topographic maps, airphotos, streamflow data, hydrological reports and geological reports, augmented by a site reconnaissance.

The scope of work included the following items as outlined in the attached Terms of Reference in Appendix I:

- identify natural water yield potential;
- identify on-stream and off-stream storage sites;
- identify maximum reservoir capacity and dam height of selected reservoir sites;
- preliminary design and cost estimate;
- comparison of selected sites based on water supply capability, capital and annual costs, operating considerations, suitability for municipal water supply and streamflow augmentation, environmental impacts and land damages;
- ranking of selected sites.

It was agreed with Alberta Environment that a total of six potential storage sites would be selected from those identified in the initial stages of the study for more detailed assessment and comparison. The locations of the six selected sites are shown on Figure 1. Several other potential sites are also shown for possible future reference during final design but are not included in the detailed comparison of this report.

Site 2 comprising of a diversion structure on Willow Creek and a reservoir in Pine Coulee, was previously studied by P.F.R.A. in the late 1950's; however, their study was never completed as a result of the decision to construct the Chain Lakes Reservoir. The mapping and

geotechnical information gathered by P.F.R.A. was made available to Klohn Leonoff Ltd. for this study. Consequently the assessment of Site 2 was based on much better site data than any of the other sites.

2.0 METHODOLOGY

2.1 Sources of Information

A list of references for all the topographic maps, airphoto coverage, reports, land classification maps, geology maps and reports, hydrogeology maps and previous geotechnical investigations, used in this study, are provided in Appendix II. In addition to these sources of information one aerial site reconnaissance was made to gather additional geological and topographical details.

2.2 Hydrology Studies

A hydrology study was carried out to determine the following key parameters.

a) Annual water yield.
b) Target storage capacity required to provide flow regulation for 60% of mean annual runoff.
c) Spillway design floods.
d) Construction diversion design floods.

The study identified these parameters in terms of catchment area so that they could be estimated for any selected site, depending on the catchment area and location within the Willow Creek Basin. The analysis, conclusions and general discussion of the surface water hydrology of the area, are reported in Appendix III.

The criteria of 60% flow regulation was selected to identify a maximum size of reservoir at any location, for preliminary comparison. The required reservoir size would be reviewed during the detailed design stage, once water demands are estimated.

The design hydrologic parameters for each of the six sites, as given on the summary graphs in Appendix III, are given below:

Site No.	Mean Annual Flow m^3/s	Mean Annual Runoff dam^3	Target Storage Capacity* dam^3	Design Spillway Capacity m^3/s	Construction Diversion Capacity m^3/s
1	3.39	107,000	76,000	900	270
2	3.36**	106,000**	73,000**	-+	3+
3	3.04	96,000	59,000	1,000	190
4	1.60	50,500	30,000	530	120
5	1.32	41,500	25,000	450	100
6	0.73	23,000	19,500	380	18

* Regulation of 60% of mean annual runoff.

** Considering Willow Creek flow at mouth of Pine Creek.

+ Considering Pine Coulee flow.

The target reservoir storage capacity, based on flow regulation of 60% of mean annual runoff, was identified for each site assuming no flow regulation by Chain Lakes. If the allowable live Storage capaicty of that reservoir were incorporated, the target reservoir storage capacity for each of the downstream potential reservoirs would be smaller by an equal amount. According to present Chain Lakes reservoir operating criteria, approximately 6000 dam^3 of storage, which is equivalent to a 1.5 m (5 foot) reservoir drawdown, is used for flow regulation.

2.3 Site Selection

Twenty-three possible reservoir sites were initially selected based on 1:50,000 scale NTS mapping. Approximate dam embankment quantities were calculated, based on this mapping, for the target reservoir storage values calculated in the hydrology study.

The sites were then listed in order of the ratio of reservoir capacity to embankment volume. Other factors such as flooded area, flooded farmsteads, length of required road relocation and flooded pipelines were identified for each site. This information was used to screen the sites in conjunction with Alberta Environment. As a result 13 sites were selected for aerial reconnaissance and further comparison.

The aerial reconnaissance was undertaken on March 9, 1984. Based on the additional site specific geological and topographical observations made during that reconnaissance, 6 of the 13 sites were selected in consultation with Alberta Environment. The rational for the final site selection was detailed in a progress report dated March 19, 1984 provided in Appendix IV of this report.

As indicated in that progress report, Site 6 was included in the final selection so that the more detailed assessment and comparison would include one site in the southern portion of the Willow Creek Basin.

Site 2 is the only off-stream site considered in this study as no other suitable off-stream sites were identified. Storage sites were considered on many of the tributary creeks to Willow Creek but the ratios of reservoir volume to dam volume were so low that these sites were eliminated early in the study.

The plains east of Willow Creek were also inspected during the site reconnaissance for off-stream storage sites that might serve as municipal water supply reservoirs supplied by pumps from Willow Creek. A number of natural depressions and potholes were examined; however, it appeared that off-stream storage could only be developed by building perimeter dykes to raise the potential water depth and minimize the flooded land area.

In addition to the six selected sites, there are other sites whose potential for development appeared nearly equal to the selected sites during the site selection phase of this study. The location of these sites are identified on Figure 1 so that they may be re-considered if necessary at a later stage.

2.4 Conceptual Design Parameters

2.4.1 Reservoir Capacity

The design reservoir capacity was determined by the lesser of the following criteria:

a) Storage capacity based on a target flow regulation of 60% of mean annual runoff.

b) Physical maximum practical storage capacity of any site as determined by the height of the valley walls less freeboard.

Reservoir capacity and area curves were calculated for four of the six selected sites based on a combination of the following:

- aerial photos to determine valley bottom width
- 1:50,000 scale NTS mapping to determine valley gradient
- aerial photos (by parallax bar) to estimate height of the valley walls.
- field observations (by range finder and clinometer) to estimate slope of valley walls.

For Site 2 at Pine Coulee, the P.F.R.A. detailed topography with 10 foot contours, was used. For Site 4 where the valley walls are not nearly as steep as at the other sites, the reservoir area and capacity curves had to be estimated using the 1:50,000 topographic maps. The storage capacity curve for this site is therefore considered to be the least accurate.

2.4.2 Dams

Geotechnical assessments for dam design were made on the basis of the following data:

- site reconnaissance
- geology and hydrogeology maps and reports
- detailed drill hole logs at Site 2 - Pine Coulee from P.F.R.A.
- Air photo interpretation
- drill hole logs on Willow Creek near the Claresholm water supply intake, from Alberta Environment
- subsoil data at the north and south dam of the Chain Lakes Reservoir project, as outlined in the design report

Earthfill dams were selected for each of the sites except Site 3 where a rockfill dam with an impervious core, was selected. Upstream dam side slopes vary from 1V:2.5H to 1V:4H depending on zoning, and expected foundation conditions. Downstream side slopes vary from 1V:2H to 1V:3H. A 6 m minimum crest width and 3 m freeboard allowance was provided for each main dam.

2.4.3 Spillways

Flipbucket type spillways were selected for each site where rock was expected to provide a suitable foundation; otherwise hydraulic jump stilling basins, were selected.

The criteria for selecting the design spillway capacity was based on the Dam Safety Guidelines by the Dam Safety Branch of Alberta Environment as outlined Below:

Reservoir Capacity	Design Flood
1,000 - 50,000 dam^3	0.5 PMF
> 50,000 dam^3	0.75 PMF

The probable maximum flood (PMF) estimates are based on envelope curves from the Saskatchewan Nelson Basin Board Studies and are reproduced and discussed in Appendix III.

2.4.4 Construction Diversions and Low Level Outlets

Tunnel diversions in combination with low level outlets were selected for five of the sites where the risk of relatively large floods is significant. However, a cut and cover low level conduit was selected for Site 2 because of the relatively low flood flow potential from its natural catchment. The required construction diversion capacity for each site was assumed to be the 25 year flood peak. The 25 year flood potential on the Willow Creek Basin was derived in the hydrology study and is presented in Appendix III in terms of catchment area.

2.4.5 Water Supply

Each of the sites are designed to provide flow regulation by controlled release through the low level outlet. Gravity diversion to other off-stream locations would not be feasible at any of the sites for any significant diversion.

2.5 Basis of Cost Estimates

Considering the very preliminary nature of this study, the cost estimates presented herein were determined from gross volumes, design capacities and major dimensions. Costs were based mainly on estimates made for other projects which have been studied in more detail and recent construction costs of similar projects. These costs were adjusted to reflect 1984 price levels. The estimated project costs presented herein, should be used only for comparing the six sites, and should be treated as order of magnitude type of estimates.

The major cost items and basis of unit costs are outlined below:

i) Dam Embankment

The total cost of the earthfill dams was calculated by multiplying the total dam volume by a unit cost of $\$6.50/m^3$. This unit cost was selected based on 22 other recent embankment projects.

The total cost of the rockfill dam with impervious core was calculated by multiplying the total dam volume by a unit cost of $\$9.00/m^3$.

ii) Spillway

The spillway costs were extrapolated from the known or estimated project costs of eleven other spillway projects. The extrapolation was based on two parameters; the spillway length and design flow capacity.

iii) Diversion Tunnel and Low Level Outlet

The cost of diversion tunnel and low level outlet were similarly determined based on eight other projects. The total costs were extrapolated based on the tunnel length and design flow capacity.

iv) Reservoir Damages

The assumed costs of reservoir damages are itemized below.

Road Relocations:	
minor gravel road	$ 50,000/km
major gravel road	$100,000/km
Bridges:	
across Willow Creek	$500,000
across Trout Creek	$300,000

Land:	
irrigated land	$5,000/ha
cultivated dryland	$2,500/ha
range pasture	$1,200/ha
valley walls	$ 750/ha
Land Clearing:	
Clearing	$1,800/ha
Farmsteads:	
large farmstead	$200,000
intermediate farmstead	$100,000
small farmstead	$ 50,000

A 40% contingency was added to each of the above to account for engineering, land conveyancing and items unaccounted for at this level of analysis.

2.6 Environmental Aspects

Various environmental and resource land classifications at each site are identified on Table 3. The classifications were determined from the published maps listed in Appendix II.

3.0 POTENTIAL STORAGE SITES

3.1 General

The location of each site is shown on Figure 1. Figures 2 to 14 show the following items for each project site:

- the reservoir plan area
- the reservoir area curves
- the reservoir capacity curves
- the advantages and disadvantages of each site
- the damsite
- a typical dam section
- a conceptual spillway section

Table 1 provides the pertinent project data for each site including location, catchment area, flow regulation potential, mean annual flow, storage capacity and details of the dam, spillway, construction diversion and low level outlet. Table 2 provides a summary comparison of each site in terms of hydrology, dam foundation conditions, structures, reservoir damages, unit cost, and environmental classification. Table 3 lists the land classification as determined from the various environmental and resource land classification maps. Table 4 provides a summary of the estimated project costs.

3.2 Site 1 - Willow Creek Near Claresholm

The damsite is on Willow Creek about 8 km northwest of Claresholm and about 7 km downstream of the confluence of Pine Creek with Willow Creek. The reservoir location and details are shown on Figure 2 and the general arrangement, including damsite, spillway, construction diversion, and low level outlet is shown on Figure 3.

The design reservoir capacity of 39,000 dam^3 is limited by the height of the valley walls. The flow regulation capability is 50% of mean annual runoff which is somewhat less than the 60% targeted, but nevertheless quite significant.

The dam foundation on the valley floor is expected to be composed of pervious layers of sand/gravel, interbedded with silt and clay. The left abutment is composed of sandstone/shale bedrock to about half the valley wall height, overlain by glacial till. The right abutment appears to be in till to the valley bottom. Glacio-lacustrine silts, sands and clays are expected to overlie the till on both abutments. As shown on Figure 3, a slurry cutoff wall is provided beneath the dam to control seepage. The dam side slopes are relatively shallow for stability.

The reservoir will flood one farmstead, 215 ha of private land and 60 ha of crown land. No road relocation would be required. The reservoir area is classified as being a Wildlife Key Area for mule deer and white tailed deer (Fish and Wildlife Division, 1981). Accoridng to the Fish Resource Maps (Fish and Wildlife Division, 1982), Willow Creek in the vicinity is populated by suckers.

3.3 Site 2 - Pine Coulee

The damsite is located in Pine Coulee near Willow Creek. The reservoir location and details are shown on Figure 4. The scheme requires a 6 m high diversion weir on Willow Creek to divert streamflow into a diversion channel to the reservoir located in Pine Coulee. An inlet chute would be required at the end of the diversion channel. Controlled releases from the reservoir to Willow Creek would be provided by a low level conduit through the left dam abutment. The general arrangement of the scheme is shown on Figure 5 and typical sections through the various structures are shown on Figure 6.

The reservoir would flood most of Pine Coulee. The design storage capacity of 50,500 dam^3 is limited by the height of the valley walls although some containment dyking is required for this volume of storage as shown on Figure 5. Consequently this reservoir provides less than the targeted flow regulation capability of 60% of mean annual runoff. Nevertheless, the regulated release rates would be higher than most of the other sites, as show on Table 1.

This site has the advantage of requiring no major service spillway or diversion works. Diversion during construction would be handled by the low level outlet constructed in advance. The project design flood could be handled either by storage above full supply level (FSL) or by reverse flow through the diversion channel to the emergency spillway in the bank of the channel.

The diversion channel from Willow Creek would require substantial excavation of about 700,000 m^3, however, the excavation costs would be offset by use of the excavated material in the dam and channel embankments.

The dam abutments are composed primarily of till overlain by a variable thickness of glacio-lacustrine sands, silts and clays. Bedrock in the abutments occurs about 7 m above valley bottom but is presently covered by colluvium.

The dam foundation on the valley floor appears to be interbedded silts and clays with some sand layers. The deposit appears to be normally consolidated. These foundation conditions will require a dam with relatively flat slopes for stability and provision for relatively large settlements. However, seepage cutoff requirements are anticipated to be minimal.

As shown on Table 2, the reservoir will flood five farmsteads, one of which is apparently abandoned. Three of these farmsteads are relatively small consisting only of one or two small buildings. There is also one large farmstead located immediately below the damsite. For purposes of the cost estimate, it is assumed that this farmstead will have to be relocated.

The reservoir also floods four roads which presently cross the coulee. It is assumed for purposes of the cost estimate, that the southerly road crossing will be re-routed across the dam, that a major causeway will be built for the next road crossing north of the dam and that a minor raising of the road embankment will be required for the most northerly crossing. It is assumed that the third crossing north of the damsite will be abandoned.

The reservoir will flood 540 ha of private land and require 6.5 km of road relocation. The flooded area is not classified as a Wildlife

Key Area for any species. (Fish and Wildlife Division, 1981). The reservoir would not have an adverse impact on the Fish resource as Pine Creek is ephermeral and thus does not provide a fish habitat.

3.4 Site 3 - Willow Creek Near Lane Creek

The damsite is located on Willow Creek about 2 km upstream of the confluence with Lane Creek. The reservoir location and details are shown on Figure 7 and the general arrangement, including the damsite spillway, construction diversion and low level outlet is shown on Figure 8.

The reservoir capacity of 59,000 dam^3 is sized for the full targeted flow regulation of 60% of mean annual runoff. The potential regulated release rate is higher than at any of the other sites (2.44/1.22 m^3/s, summer/winter).

The damsite is in a narrow rock gorge with abutments composed mainly of sandstone. The bedrock is jointed with bedding planes and exhibits some weathering. The bedrock is overlain by till. Bedrock on the valley floor is expected to be close to the riverbed and, is also expected to exhibit some surficial weathering. These foundation conditions, though excellent with regard to stability considerations, are expected to require a grout curtain across the valley floor and on the abutments to control seepage.

This site may lend itself to the use of a rockfill concrete faced dam which could be more economical than the rockfill embankment selected for the purposes of this report. However, for this level of study the rockfill shell and impervious core section design was selected for uniformity and comparison purposes.

The narrow valley gives a small dam volume relative to the reservoir storage capacity such that the ratio of reservoir volume to dam volume is the second highest of the sites considered.

Reservoir damages are comparatively small at this site. The reservoir will flood one large farmstead, 260 ha of private land and 35 ha of crown land.

The reservoir area is not classified as a Wildlife Key Area (Fish and Wildlife Division, 1981) but Willow Creek in that vicinity supports rainbow trout, eastern brook trout, mountain whitefish and suckers (Fish and Wildlife Division, 1982).

3.5 Site 4 - Willow Creek Below Chain Lakes

The damsite is located on Willow Creek, about 2 km upstream from the confluence with South Willow Creek, and about 10 km southeast of Chain Lakes Reservoir. The reservoir location and details are shown on Figure 9 and the general arrangement including the damsite, spillway, construction diversion and low level outlet is shown on Figure 10.

In addition to the main dam situated in a narrow rock gorge, a small dyke about 2 m high, will be required across a saddle to the west of the dam. This site requires quite a small embankment volume relative to reservoir storage. The ratio of reservoir volume to dam volume is the highest of the sites studied.

The reservoir capacity of 30,000 dam^3 is sized for the full targeted flow regulation of 60% of mean annual runoff. The potential regulated release rate is somewhat lower than Site 1, 2 and 3 (1.28/0.64 m^3/s, summer/winter).

Both abutments of the main dam are expected to be in bedrock to the dam crest level. Bedrock is also assumed to occur close to the riverbed level. The bedrock is expected to be jointed sandstone with bedding planes, becoming tighter with depth from the surface. The bedrock surface will be weathered, particularly along bedding planes. The foundation conditions are assumed to be inferior to Site

3 and an earthfill dam has been selected accordingly. If actual foundation conditions are better, a rockfill dam with impervious core like Site 3 Would be more suitable.

The reservoir damages at this site would be fairly significant. Two intermediate sized farmsteads will be flooded and 6.5 km of road will have to be relocated involving a bridge across Willow Creek. About 400 ha of private farmland would be flooded.

The flooded area is not classified as a Wildlife Key Area (Fish and Wildlife Division, 1981), however, Willow Creek in this vicinity provides habitat for rainbow trout, eastern brook trout, mountain whitefish and suckers (Fish and Wildlife Division, 1982).

3.6 Site 5 - South Willow Creek

The damsite is located on South Willow Creek, about 3 km upstream of the confluence with Willow Creek. The reservoir location and details are shown on Figure 11 and the general arrangement including the damsite, spillway, construction diversion and low level outlet is shown on Figure 12.

The reservoir capacity of 25,000 dam^3 is sized for the full targeted flow regulation of 60% of mean annual runoff. The potential regulated release rate is lower than sites 1 to 4 (1.06/0.53 m^3/s, summer/winter).

The unit cost of water storage at this site is higher than any of the other sites.

The left abutment is bedrock and is expected to be composed of interbedded sandstone and shale with some weathering especially at joints and bedding planes. The right abutment is believed to consist of glacio-lacustrine silts and clays overlying moraine (till). The dam foundation on the valley floor is expected to be composed of gravel interbedded with silts and sand.

These foundation conditions will require seepage control measures on the left abutment and valley floor.

The reservoir damages are comparatively small at this site. The reservoir will flood one small farmstead and 200 ha of private land. About 1.6 km of road will have to be relocated.

The reservoir area is classified as being a Wildlife Key Area for moose (Fish and Wildlife Division, 1981) and South Willow Creek is classified as supporting rainbow trout (Fish and Wildlife, 1982).

3.7 Site 6 - Trout Creek

The damsite is located on Trout Creek, about 6 km west of the confluence of Trout Creek and Willow Creek. The reservoir location and details are shown on Figure 13 and the general arrangement including the damsite, spillway, construction diversion and low level outlet is shown on Figure 14.

The reservoir storage capacity of 12,000 dam^3 is limited by the height of valley walls and thus provides less than the targeted flow regulation of 60% mean annual runoff. The reservoir is the smallest of all the sites considered and provides the least amount of flow regulation. The ratio of reservoir volume to dam volume is relatively low.

Both dam abutments are bedrock overlain by till and a surficial layer of glacio-lacustrine silts, sands and clay. Colluvium composed of a mixture of silts, sands and gravels, occurs at the base of the slope, particularly at the right abutment. The bedrock is expected to be jointed with bedding planes, exhibiting weathering especially along bedding planes. The valley floor is expected to consist of sands and gravels, interbedded with silts and sand. These foundation conditions will require a seepage cutoff to bedrock on the valley floor and a grout curtain at the abutments.

Reservoir damages appear to be minimal. The reservoir will flood about 130 ha of private land but will not flood any farmsteads and will not require any road relocations.

There may be a significant environmental impact as the area is classified as a Wildlife Key Area for great blue heron, mule deer and white tailed deer (Fish and Wildlife Division, 1981). Trout Creek is classified as supporting rainbow trout, cutthroat trout and suckers (Fish and Wildlife Division, 1982).

4.0 SUMMARY AND CONCLUSIONS

This study was in essence a "desk top" study to identify and compare potential on-stream and off-stream reservoir sites in the Willow Creek Basin.

Since water supply requirements are not known in the basin, a criterion for flow regulation was set at 60% of the mean annual flow occuring at each potential site, in order to assess reservoir capacity requirements and height of dams, etc.

Many sites were initially identified but upon more detailed review and site reconnaissance, these were reduced to six sites for purposes of this report. Site 2 is the only site which is not an "on-stream site" in the true sense, as it involves a diversion structure and channel from Willow Creek to a reservoir in Pine Coulee. The coulee has a relatively small catchment area and does not require a major spillway or diversion structure. Site 6 on Trout Creek was included in order to identify the costs and degree of flow regulation potential on Trout Creek. Though this site appears to be a possible dam site, its storage capacity and flow regulation capability is much smaller than any of the other sites, and the unit cost of storage is relatively high.

Potential sites for "off-stream" storage were sought both during the initial review of topographic mapping and during the aerial reconnaissance. However, no significant site was identified other than the Pine Coulee Site. Mud Lake has been identified and well documented in previous reports for off-stream storage for the LNID and has therefore not been addressed in this report.

It would appear that if a small, local demand is identified, pumped off-stream storage lagoons will be the most economical alternative as opposed to on-stream storage.

The environmental impact of each site has been assessed in terms of various classifications derived from published maps. As indicated in Table 3, the capability for waterfowl, outdoor recreation, forestry and agriculture is limited at each site. On the other hand, the reservoir area at Sites 1, 5 and 6 are classified as a Wildlife Key Area for one or more species of Ungulates and Colonial Nesters. Also one or more species of sport fish and presently populated Trout Creek, South Willow Creek and the upper reaches of Willow Creek, in the vicinity of Sites 3, 4, 5 and 6 as indicated on Table 3. However, only suckers occur at Site 1 and no fish presently occur above Site 2 in Pine Creek.

The six sites examined have been "ranked" from various perspectives as shown in Table 5 below. These are somewhat arbitrary rankings and subject to review upon further study. If should be noted that Sites 2 and 3 provide the best flow regulation capability enabling controlled releases in the summer and winter of 2.4 m^3/s and 1.2 m^3/s respectively. Relatively high flow regulation capability is also provided by Site 1.

TABLE 5

PRELIMINARY RANKING

Site No.	Unit Cost of Storage	Flow Regulation	Location* Downstream	Reservoir Damages	Overall Rank
1	5	3	1	3	4
2	2	1	2	6	1
3	1	1	3	4	1
4	3	4	4	5	3
5	6	5	5	2	5
6	4	6	N.A.	1	6

* It is assumed that a site located further downstream is preferable as it would be closer to the likely source of winter demand and the outflow would be less likely to freeze up during extremely cold winters.

Of the six sites it would appear that Sites 2, 3 and 4 are the most suitable. Of these, Sites 2 and 3 appear to have the best potential. Site 2 may have a greater sociological impact and Site 3 may have a greater environmental impact.

The cost of each project was plotted on Figure 15 for comparison with other projects in Southern Alberta. The reservoir cost curves on Figure 15 were previously derived by Klohn Leonoff (see reference in Appendix II) in conjunction with the South Saskatchewan River Basin Planning Program. The comparison is quite good considering the level and accuracy of the study and that of the cost curves.

5.0 RECOMMENDATIONS

In carrying out this preliminary study it became evident that additional information would be useful in assessing the basin storage potential and the desirable location of that storage. In this regard the following recommendations are made:

a) A study should be carried out to determine existing and potential water supply requirements within the basin including municipal, farm, industry and environmental needs.

b) This preliminary planning study should be reviewed after the water supply demands are identified to ascertain the most suitable sites for meeting the basin water supply demands. This review should include alternate means of meeting site specific demands such as small off-stream storages or groundwater sources.

c) Further topographic mapping and a limited geotechnical exploration program should be carried out for those sites which are found to meet the demand requirements.

d) A more detailed study should be undertaken of selected sites involving more accurate layouts and quantities, to more closely define project costs.

TABLE

PROJECT SI

SITE NO.	CREEK	LOCATION OF DAM	CATCHMENT AREA Km^3	RESERVOIR AREA ha	FLOW REGULATION[1] SUMMER/WINTER m^3/s	MEAN ANNUAL RUNOFF dam^3	STORAGE[2] CAPACITY dam^3	DAM[2] HEIGHT m	DAM[2] LENGTH m	DAM[2] VOLUME dam^3
1	Willow	12-13-28-W4	1136	285	2.26/1.13	107,000	39,000	27	460	1,100
2	Pine	34-13-28-W4	109 natural 1065 with diversion	540	2.42/1.21	106,000	50,500	21	480	1,200 dam and dykes
3	Willow	2-14-30-W4	680	295	2.44/1.22	96,000	59,000	46	200	480
4	Willow	15-14-1-W5	355	400	1.28/0.64	50,500	30,000	24	170	180
5	South Willow	5-14-1-W5	258	200	1.06/0.53	41,500	25,000	29	610	780
6	Trout	34-11-28-W4	420	130	0.48/.24 Approx.	23,000	12,000	23	265	410

1. Flow regulation based on the following criteria:
   - summer 6 month flow = 2 x winter 6 month flow
   - flow regulation = 60% of mean annual runoff (assuming 10% chance of reservoir empty) unless otherwise indicated on Table 2.
2. Reservoir+dam details based on 1:50,000 NTS maps and air photo interpretation except for Site 2 which is based on mapping by PFRA.

TABLE 1

PROJECT SITE DATA

DAM[2]		SPILLWAY			CONSTRUCTION DIVERSION			TYPE OF LOW LEVEL OUTLET	OTHER
LENGTH m	VOLUME dam^3	TYPE	LENGTH[3] m	CAPACITY m^3/s	TYPE[4]	CAPACITY m^3/s	LENGTH m		
460	1,100	hyd. jump stilling basin	147	900	Tunnel	270	200	Tunnel[4]	
480	1,200 dam and dykes	-reverse flow through diversion channel -emergency spillway provided	-	-	coffer dam and conduit	3	200	Conduit	-6m high diversion weir required on Willow Creek. -Diversion channel from Willow Creek (700,000m^3 excavation) -side valley dykes required.
200	480	flip bucket	115	1000	Tunnel	190	225	Tunnel[4]	
170	180	flip bucket	140	530	Tunnel	120	180	Tunnel[4]	
610	780	hyd. jump stilling basin	268	450	Tunnel	100	290	Tunnel[4]	
265	410	flip bucket	70	380	Tunnel	18	200	Tunnel[4]	

3. Length of spillway from headblock to end of flip bucket or concrete lined stilling basin.

4. Construction diversion tunnel will also serve as low level outlet.

TABLE 1

TABLE 2

PRELIMINARY COMPARISON OF POTENTIAL RE

SITE NO.	HYDROLOGY	DAM FOUNDATION	OTHER STRUCTURES	RATIO OF RESERVOIR VOL TO DAM VOL.	RES	
					LAND	FARMST
1	- provides flow regulation for about 50% of mean annual runoff. - storage capacity is 37,000 dam^3 less than that required for 60% flow regulation.	- expect pervious foundation will require seepage control measures.	- relatively high spillway capacity and construction diversion capacity.	35	- 215 ha private 60 ha crown - 70% rangeland 30% treed	1 inte
2	- provides flow regulation for about 54% of mean annual runoff. - storage capacity is 22,500 dam^3 less than required for 60% flow regulation.	- soft silt and clay foundation will require shallow dam side slopes. - weir and diversion dyke on pervious floodplain and will require seepage control.	- requires gravity diversion from Willow Creek. - no spillway required.	42 Including dam & dykes	- 540 ha private - 99% rangeland 1% cultivated	1 aban 3 smal 1 inter 1 large dam)
3	- provides flow regulation for 60% of mean annual runoff.	- stable rock abutments and expect rock foundation. - rock will require grouting.	- good spillway site on rock foundation. - relatively long tunnel. - relatively high spillway capacity and construction diversion capacity.	123	- 260 ha private and 35 ha crown - 80% rangeland 20% treed	1 large
4	- provides flow regulation for 60% of mean annual runoff.	- stable rock abutments and expect rock foundation. - rock will require grouting.	- spillway on rock foundation	167	- 400 ha private - 100% rangeland	2 inter
5	- provides flow regulation for 60% of mean annual runoff.	- expect pervious foundation will require seepage control measures.	- spillway on rock foundation. - relatively long spillway and tunnel.	32	- 200 ha private - 70% rangeland 30% treed	1 small
6	- storage capacity is 7,500 dam^3 less than required for 60% flow regulation	- stable rock abutments. - expected pervious foundation will require seepage control measures.	- spillway on rock foundation. - relatively short spillway.	29	- 130 ha private - 70% rangeland 30% brush	0

[1] Wildlife Key Area maps, Fish and Wildlife Division, Alberta Energy and Natural Resources, 1981

[2] Fish Resource Maps, Fish and Wildlife Division, Alberta Energy and Natural Resources, 1982

AL RESERVOIR SITES

RESERVOIR DAMAGES		UNIT CAPITAL COST $/dam^3	ENVIRONMENTAL IMPACT		RANK
FARMSTEADS	ROAD/BRIDGE RELOCATION		MAP CLASSIFICATION [1] (See Table 3 for details)	FISH SPECIES [2]	
1 intermediate	0	790	- Wildlife Key Area for Mule Deer and White Tailed Deer.	Sucker	4
1 abandoned? 3 small 1 intermediate 1 large (D/S of dam)	- 1 major causeway required - 6.5 km road	439	-	-	1
1 large	0	424	-	Rainbow Trout Eastern Brook Trout Mountain Whitefish Sucker	1
2 intermediate	- 1 bridge - 6.5 km road	543	-	Rainbow Trout Eastern Brook Trout Mountain Whitefish Sucker	3
1 small	- 1.6 miles road	1038	- Wildlife Key Area for Moose	Rainbow Trout	5
0	0	725	- Wildlife Key Area for Great Blue Heron, Mule Deer and White Tailed Deer.	Cutthroat Trout Rainbow Trout Sucker Spawning area for Trout	6

TABLE 2

TABLE 3

RESOURCE AND ENVIRONMENTAL LA

SITE NO.	FISH RESOURCE MAPS-SPECIES Fish and Wildlife Division, AENR, 1982	WILDLIFE KEY AREAS Fish and Wildlife Division, AENR, 1981	LAND CAPABILITY FOR WATERFOWL[1] Canada Land Inventory	LAND CAPABILITY FOR RECREATION[2] Canada Land Inventory
1	Sucker	Mule Deer White Tailed Deer	6B	5AOK
2	-	-	6T	5LQO
3	Rainbow Trout Eastern Brook Trout Mountain White Fish Sucker	-	6TB	4VAK
4	Rainbow Trout Eastern Brook Trout Mountain Whitefish Sucker	-	6T	4VQP
5	Rainbow Trout	Moose	6T	4VAK
6	Cutthroat Trout Rainbow Trout Sucker	Mule Deer White Tailed Deer Great Blue Heron	6T	4AVQ

CLASSIFICATION NOTES:

1. Land Capability for Water Fowl
   Class: 6 Severe limitations to the production of water fowl.
   Subclass: B Fast flowing water
   T Adverse Topography

2. Land Capability for Outdoor Recreation
   Class: 4 Moderate Capability
   5 Moderately Low Capability
   Subclass: See Canada Land Inventory Legend

TABLE 3

ONMENTAL LAND CLASSIFICATION

LITY ION[2] nd y	LAND CAPABILITY FOR FORESTRY[3] Canada Land Inventory	SOIL CAPABILITY FOR AGRICULTURE[4] Canada Land Inventory	PRESENT LAND USE[5] Canada Land Inventory	ECOLOGICAL LAND CLASSIFICATION AND EVALUATION LIVINGSTONE-PORCUPINE AENR
	-	5 ST (80%) 6 T (20%)	U 30% K 60% Some A,P & E	Shrubs, Aspen, Willow
	-	6 T (60% 5 S (40%)	mainly K some A&P	N/A
	7 MC	6 T(80%) 5 ST (20%)	mainly K some T&P	Shrubs, Aspen, Willow
	7 MC (70%) 5 M (30%)	5 C	mainly K some P	N/A
	5 M (60%) 7 MU (40%)	5 C (80%) 6 T (10%) 6 W (10%)	mainly K some U	N/A
	-	5 S (80%) 6 T (20%)	K	Aspen, Willow

3. Land Capability for Forestry
   Class: 5 Severe limitations to growth of commercial forests
   7 Severe limitations which preclude the growth of commercial forests
   Subclass: See Canada Land Inventory Legend

4. Land Capability for Agriculture
   Class: 5 Severe limitations that restrict their capability to producing perennial forage crops, and improvement practices are feasible
   6 Soils in this class are capable only of producing perennial forage crops and improvement practices are not feasible
   Subclass: See Canada Land Inventory Legend

5. Present Land Use
   Class: A Light Brown - Cropland
   P Dark Yellow - Improved Pasture and forage crops
   K Light Yellow - Improved Pasture and Range Land
   T Dark Green - Productive Woodland
   U Light Green - Non-Productive Woodland
   E Silver - Mines, Quarries and Gravel Pits

TABLE 3

TABLE 4

CAPITAL COST SUMMARY[1]

COST ITEM	SITE 1	SITE 2	SITE 3	SITE 4	SITE 5	SITE 6
Embankments	$10,010,000	$10,850,000	$6,050,000	$1,640,000	$ 7,100,000	$3,730,000
Spillway	10,180,000	-	9,070,000	6,340,000	10,130,000	2,670,000
Diversion Tunnel	9,980,000	-	9,070,000	5,740,000	7,980,000	2,110,000
Low Level Outlet[2]	-	1,820,000	-	-	-	-
Diversion[3]	-	6,000,000	-	-	-	-
RESERVOIR DAMANGES						
-Road Relocation	-	910,000	-	910,000	220,000	-
-Bridges	-	-	-	700,000	-	-
-Clearing	160,000	-	130,000	-	170,000	-
-Land Acquisition	350,000	850,000	400,000	670,000	300,000	200,000
-Farmsteads	140,000	630,000	280,000	280,000	70,000	-
-Causeways	-	1,120,000	-	-	-	-
TOTAL[4]	$31,000,000	$22,000,000	$25,000,000	$16,000,000	$26,000,000	$8,700,000

1. Costs include 40% contingency.
2. Cost of low level outlet included in Diversion Tunnel except for Site 2.
3. Diversion weir on Willow Creek and diversion channel.
4. Total cost is rounded to 2 significant figures.

APPENDIX

NOT

FILMED